Studies to Establish Biological Design Criteria for Fish Passage Facilities: Prototype Testing of a Cylindrical Dewatering Screen at McNary Dam, 2001-2002

Michael H. Gessel, Benjamin P. Sandford, and John W. Ferguson

Report of research by

Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

for

Walla Walla District
North Pacific Division
U.S. Army Corps of Engineers
201 North 3rd
Walla Walla, Washington 99362-1876
Delivery Order W68SBV00358064

March 2004

EXECUTIVE SUMMARY

Juvenile salmonid bypass facilities at hydroelectric dams on the Snake and Columbia Rivers are used to route fish past the dam through a non-turbine route and to collect juveniles for subsequent transportation and release below the dams. A major component of these systems is the primary dewatering screen, which removes excess water from the fish bypass channel and diverts juvenile migrants to holding and collection facilities. A combination of vertical and floor dewatering screens is used as the primary dewatering system at several dams on the Snake and Columbia Rivers.

Problems occur at these sites when debris accumulates on the screens, and this often leads to mechanical breakdowns of the screen cleaning systems and structural components, as well as fish injury. Repairs require that gatewell orifices leading to the bypass channel be closed, which can cause fish to hold in the gatewells and delay their downstream migrations.

A new and untested method of removing or passing debris from juvenile bypass systems is the cylindrical dewatering screen (CDS). The CDS allows fish and some flow to be carried downstream while the flow that is being dissipated impinges debris on the inner walls of rotating screen sections. As the screens rotate, impinged debris rises above the water level and either falls or is washed off the inner walls into a debris flume.

A prototype CDS was tested at McNary Dam during both the 2001 and 2002 juvenile salmon migrations. The prototype consisted of five sections of rotating screen (each section 1.2 m od × 1.5 m long), an entrance channel (4.9 m long × 1.2-1.9 m wide × 1.5 m high) leading to the screened sections, and an exit channel (5 m long × 1.2 m wide × 1.5 m high) at the downstream end of the screened sections. The CDS and both entrance and exit channels were hydraulically designed to have gradual increases in water velocity, but not to exceed 10 cm/sec through the dewatering screen (impingement flow). Test fish were run-of-the-river juvenile Pacific salmonids (*Oncorhynchus* spp.) collected from gatewells at McNary Dam. Tests were conducted on both spring (yearling) and summer (subyearling) migrants.

Installation of the CDS was completed in late June 2001. In 2001, after a series of flow evaluation tests to verify that designed flow velocities were met, we completed only a few tests with subyearling chinook salmon before high water temperatures halted the tests. Debris testing was conducted during late summer 2001.

Results for the 2001 tests indicated that injury or descaling of subyearling chinook salmon was minimal, and that under standard operating conditions, very little debris impinged on the screen for more than a few seconds. One potential problem was observed when sodden wood chips were the primary type of debris used in the test, and when the CDS was not rotating. Under these unusual flow conditions, the wood chips completely covered the floor of the last two sections of CDS (to about a depth of 8-10 cm).

Results from the 2002 tests with very small subyearling chinook (pre-smolts about 50 mm fork length) and run-of-the-river spring or summer migrants indicated that little if any obvious external injury or descaling could be attributed to the CDS. Several tests that used a mixture of aquatic vegetation/wood chips/leaves in conjunction with subyearling chinook salmon showed a small increase in descaling associated with the debris (from about 0.5 to 1.1%).

Test results from two years of study indicated that the prototype CDS produced very low rates of descaling on run-of-the-river juvenile salmon. However, the CDS removed very little debris. Most debris was simply washed downstream through the CDS with the flow and would eventually require removal by traditional means.

CONTENTS

INTRODUCTION

McNary Dam is the first dam downstream from the confluence of the Columbia and Snake Rivers, influencing anadromous fish migrations from both river systems. It was completed in 1954 and lies at River Kilometer 467 (River Mile 292). It is equipped with 14 turbine units, 22 spillbays, a navigation lock, and a juvenile fish bypass system, and is operated by the U.S. Army Corps of Engineers (USACE).

The juvenile fish bypass system diverts downstream migrating salmonids either for transport to a release site below Bonneville Dam or for return to the river below McNary Dam. Extended-length submersible bar screens (ESBS) are used to divert juvenile salmonids (*Oncorhynchus* spp.) from turbines into gatewells from which the juveniles volitionally exit through orifices and enter the bypass channel.

During much of the spring juvenile migration, large amounts of debris from a variety of sources (aquatic vegetation, leaves, branches, trash, etc.) is also present in the river. The ESBSs also divert this debris into the gatewells, which can create problems for the migrants as well as disrupt operation of the bypass system. Large pieces of debris can lodge in an orifice or in the mechanically operated brush sweep that cleans the inclined dewatering screen at the downstream end of the bypass channel.

This research addressed issues related to objectives stated in the USACE Northwestern Division's Anadromous Fish Evaluation Program, and the National Marine Fisheries Service (NMFS) biological opinion for operation of the federal Columbia River Power System (NMFS 2000). Our goal was to determine how well juvenile salmonids passed through a scaled prototype CDS and their physical condition after passage. Additionally, we monitored debris accumulation and/or removal from the prototype CDS. Data collected during this evaluation will be used to provide biological design criteria for future fish passage facilities. This study was originally scheduled to begin during the spring juvenile migration of 1999, but did not begin until late summer of 2001 because of construction delays and design modifications. Specific research objectives in 2001 and 2002 were:

1. Evaluate the effects of the CDS on passage of juvenile salmonids.

2. Evaluate the effects of a prototype CDS on juvenile salmonid physical condition by monitoring for descaling and/or obvious external injury.

3. Evaluate debris passage and/or collection through the CDS.

The juvenile bypass system in operation at McNary Dam is similar to those used at other collector dams on the Snake and Columbia Rivers. The primary dewatering screen is a combination vertical and floor dewatering screen installed at the south end of the juvenile fish bypass system collection channel. Components include panels of wedge wire screen that are used to dissipate excess water and divert fish into a separate flume or pipe for delivery to the juvenile collection facility. A mechanical brush system keeps debris from accumulating on the screen panels and allows the flow to carry debris downstream.

The juvenile bypass channel at McNary Dam is approximately 4 m wide and 3 m deep near the primary dewatering screen. There are a total of 84, 0.3-m (12-in) diameter orifices that can pass fish and water into the bypass channel (14 turbines × 3 gatewells × 2 orifices). Standard operating procedures require that at least one orifice in each gatewell be open when a turbine is operating, and total flow through the bypass channel will approach 17-20 m^3/sec (600-700 ft^3/sec) when all turbine units are in operation (depending upon forebay elevation).

With these flow conditions, it was impossible for a full-size prototype CDS to be tested. Therefore, a model of the prototype was designed and installed for testing at McNary Dam (Figure 1). The model was scaled to one-quarter of the physical dimensions of the CDS. However, flows within the system were designed to mimic those that would be present in a full-size prototype to ensure that velocities encountered by migrating salmonids in the prototype would be present in the model.

This report details our biological evaluation of the CDS. Hydraulic conditions within the CDS (acceleration and impingement velocities) were consistent with criteria developed by NMFS for a juvenile salmonid bypass system (NMFS 1995). Hydraulic design and construction criteria are being discussed in a separate report by personnel from the Hydraulic Design Division, Walla Walla District of the USACE.

The prototype consisted of five sections of rotating screen (each section 1.2 m od and 1.5 m long). Screen panels were made from 0.48-cm (3/16-in) wedge wire with 0.16-cm (1/8-in) gaps between the parallel wires. Upstream from the CDS was a rectangular approach flume (8.2 m long × 2 m wide × 1.5 m high), followed by an entrance transition section (rectangular-circular; 4.9-m long). Downstream from the CDS was a 5-m long exit transition section (circular - "U" shaped). The CDS and both entrance and exit channels were hydraulically designed for a gradual increase in velocity, with impingement flow through the dewatering screen not to exceed 10 cm/sec. Screen rotation could be varied, but was set at 0.5 rpm for all tests.

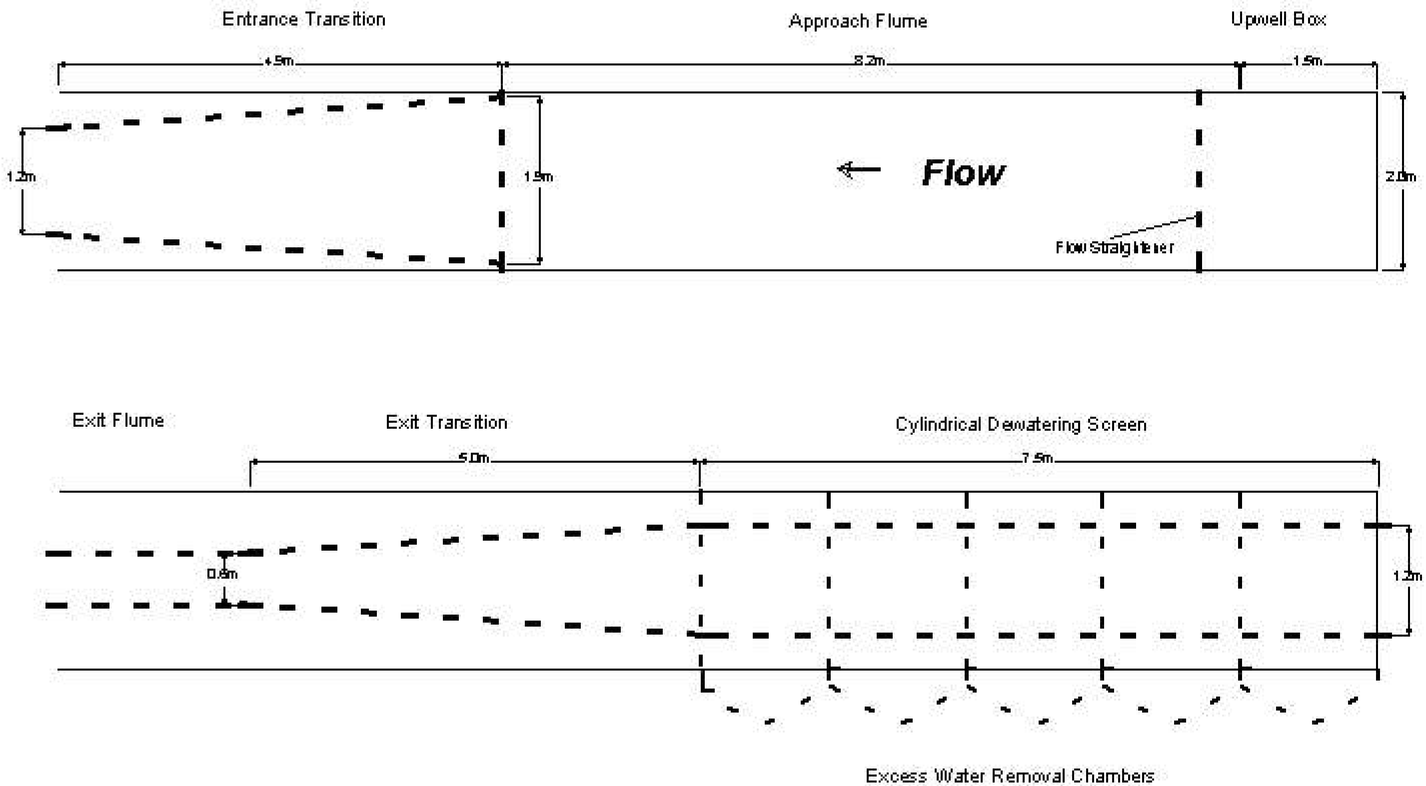

Figure 1. Overhead view of the cylindrical dewatering screen (model CDS) that was field tested during the 2001 and 2002 juvenile salmonid migrations at McNary Dam. The figure shows the CDS split into two sections. See also Gessel (2002), section 1.

All CDS tests were conducted using a standard flow condition that started with 20.9 m^3/sec (59.3 ft^3/sec) being introduced into the approach flume. Flow velocity through the approach flume averaged 0.7 m/sec (2.3 ft/sec) and the depth of the flow was 1.1 m (3.5 ft). Flow through the entrance transition section increased from 0.7 to 1.5 m/sec (2.3 to 5.0 ft/sec) at the exit point. The length of this transition was 4.9 m (16 ft) so that the rate of increase was 6.0 cm/sec (0.2 ft/sec).

The CDS operated on a slight incline so that water depth at the entrance was 1.0 m (3.2 ft), which was 80% of the diameter of the CDS, and approximately 0.3 m (1.0 ft) at the exit. The CDS was operated such that velocity through its length was 1.5 m/sec (5.0 ft/sec), and impingement velocity (or through-screen velocity) was 10 cm/sec (0.4 ft/sec) or less. To achieve these criteria, each of the five screen sections were individually chambered and valved. Water could then be removed at a prescribed volume for each. Dewatered flow volumes were set at 2.5, 3.0, 3.3, 3.1, and 2.9 m^3/sec (7.0, 8.5, 9.25, 8.7, and 8.1 ft^3/sec) for the first (upstream) through the fifth (downstream) screen sections, respectively.

During hydraulic testing for flow verification, horizontal flow ranged from 1.4 to 1.5 m/sec (4.55 to 4.75 ft/sec), and through-screen flow was 0.1 m/sec (0.4 ft/sec) except at the very downstream end of the CDS, where it was measured at 0.2 m/sec (0.65 ft/sec). Velocity through the exit transition section began at 1.5 m/sec (5.0 ft/sec) and increased to 1.9 m/sec (6.2 ft/sec) over the 5.2 m (17 ft), an acceleration rate of 0.2 m/sec^2.

OBJECTIVE 1:Evaluate the Effects of a Cylindrical Dewatering Screen on Passage of Yearling and Subyearling Chinook Salmon

Approach

Fish used for the CDS tests were dip netted from gatewells at McNary Dam using a dipbasket similar to that described by Swan et al. (1979), and then transported to the CDS on the tailrace deck for testing the next day. Just prior to testing, fish were transferred from the holding tanks to a release tank positioned over the center of the approach flume and just downstream from the flow straightener (see Figure 1). This release tank was equipped with a quick-opening gate valve and a removable false wall that allowed us to partition the tank so that fish could be released with only a minimal loss of water from the main tank.

Fish releases were generally made in small groups (10-30 fish). A release “group” was separated from the main body of test fish using the false wall. The gate valve was then opened and the “partitioned” fish were released into an open-ended trough that extended to a depth of about 0.6 m (2 ft) into the channel flow. The trough was 1.8 m long by 0.6 m wide (6 × 2 ft), suspended from the grating that covered the approach flume, and the interior was painted flat black. When fish are “dumped” into a flume or tank, the most prevalent reaction appears to be an almost frenetic dispersal. Since it was open ended, and flow passed through unobstructed, the narrow trough appeared to provide a “channeling” effect that kept fish near the center of the approach flume and caused or allowed them to orient into the flow (positive rheo-taxis) prior to moving downstream.

Tests were generally conducted from mid morning (1000) through mid-afternoon. No examination of the fish occurred until after they passed through the CDS and were recaptured. After passing through the exit transition section the water/fish emptied onto a section of perforated plate (secondary dewatering area). This allowed us to dissipate most of the water and shunt the fish into a 10.2-cm (4 in) diameter flex hose which directed the fish into a small holding tank. Species identification, physical condition, and fork length data were collected on all recaptured fish.

An underwater video camera was used during the summer juvenile migration at selected observation points within the CDS system (high turbidity precluded the use of cameras during the spring juvenile migration). The underwater camera was placed near the surface and oriented to view fish from above. Also, a 40 by 60-cm (16 × 24-in) piece of 6-mm (1/4 in) clear plexiglass was placed over the camera lens. The plexiglass was oriented horizontally and parallel to the flow to minimize flow disruption and any subsequent influence on fish behavior. This maintained a clean viewing window when the camera was placed at the water surface. It also helped keep uniform flows across the camera lens by eliminating air bubbles that would adhere to the camera lens support when the camera was positioned in the shallower water at the downstream end of the CDS. Observation points were the entrance to the upstream transition section, the entrance to the CDS, several sites within the CDS, and near the exit of the CDS.

Results and Discussion

Only two tests with fish were conducted during the 2001 field season. We were unable to begin until early July, and within a few days, the river water temperature was at the upper test limit (28°C), which eliminated any additional fish handling opportunities. A total of 985 subyearling chinook salmon were released, and nearly 90% (876/985) of the fish passed through the CDS within 2 hours after release.

During 2002, testing of naturally migrating juvenile salmonids began on 19 May and ended on 21 July due to rising water temperature and low numbers of subyearling chinook salmon. Table 1 gives the species and numbers of all fish released during the two-year study period. During the 2002 juvenile migration, we released 6,855 subyearling chinook salmon, 878 yearling chinook salmon, 221 steelhead, 146 coho salmon, and 459 sockeye salmon for a total of 8,559 fish.

After fish were first released into the approach flume, there was always a short delay of 10-20 minutes before they entered the entrance transition section. However, no areas within the entrance transition, dewatering screen, or exit transition appeared to create any consistent barriers to fish passage. Based on observations during the tests and on video recordings, some fish from nearly all the tests moved upstream and retraced their passage route. This type of movement appeared to occur with all species and was most evident at the transition areas where the configuration of the system changed.

Once fish began moving, the vast majority simply passed downstream with the flow (Gessel 2002, Video 2). However, at the end of nearly all tests, some fish remained in the approach flume. Whether this delay was a behavioral reaction to our handling techniques is not known. One consistent pattern did occur: fish that failed to exit the CDS (those that remained in the approach flume) were always larger than their species counterparts that did exit.

Table 1. Number of juvenile salmonids used during the cylindrical dewatering screen fish passage tests conducted at McNary Dam during the spring and summer juvenile migration season, 2001 and 2002. Subyearling chinook tested on 4/12-5/15 were hatchery fish from Little White Salmon National Fish Hatchery. All tests were conducted under standard flow conditions. Shading indicates test dates when a mixture of debris was released with the fish.

Date	Yearling chinook	Coho	Steelhead	Sockeye	Subyearling chinook
7-11-2001					543
7-13-2001					550
4-12-2002					1,200
4-25-2002					1,200
5-14-2002					1,200
5-15-2002					1,200
5-17-2002	73	1	6	137	5
5-23-2002	107	3	3	75	10
6-04-2002	277	79	145	74	175
6-06-2002	72	23	20	60	117
6-07-2002	53	22	16	12	72
6-21-2002	1	1	1	2	249
6-25-2002					1033
6-27-2002					565
6-28-2002	2			1	541
7-02-2002	3				422
7-03-2002	4			3	666
7-09-2002	47	2		19	889
7-11-2002	14				512
7-12-2002	9			5	422
7-16-2002	33			3	876
7-18-2002	5			1	165
7-19-2002	6			1	201

Table 2 gives the fork length data we collected during the 2002 study year. For each species tested, the average fork length of fish that remained in the approach flume was significantly larger than that of fish exiting the flume ($P = 0.0$, 0.0002, 0.0139, 0.0222, and 0.0; for yearling chinook, coho, steelhead, sockeye, and subyearling chinook, respectively).

Table 2 also gives the percentage of fish for each species that failed to exit. The highest exit percentage was seen in smaller fish, which have reduced swimming capabilities (subyearling chinook and sockeye) relative to larger fish. Whether this "passage efficiency" is related to fish size or results from species interaction can only be surmised, but passage was highest (91.8%) for subyearling chinook during the summer juvenile migration, when numbers of other salmon species are few.

Table 2. Fork length (mm) of fish tested in the cylindrical dewatering screen during the 2002 field season at McNary Dam.

	Yearling chinook	Coho	Steelhead	Sockeye	Subyearling chinook
	Fish that exited the CDS				
Mean fork length	137	140.5	203.2	102.4	100.7
SD	14.4	16.4	34.1	12.4	9.1
SE	0.6	2.3	5.1	0.7	0.1
Median	136	143	210	101	100
Fish count	542	49	44	303	4,903
	Fish that did not exit the CDS				
Mean fork length	148.9	150.3	217.5	110	103.3
SD	20.4	7.4	26	19.4	8.5
SE	1.7	0.9	2.5	3.2	0.4
Median	145	150	215.5	106	103
Fish count	145	62	106	36	438
No exit (%)	21.1	55.9	70.7	10.6	8.2
Exited fork length vs. non-exited fork length					
t	6.62	3.89	2.49	2.3	5.92
P	0.0	0.0	0.0139	0.0222	0.0

OBJECTIVE 2: Evaluate the Effects of a Cylindrical Dewatering Screen on Fish Condition by Monitoring Descaling and Obvious External Injury

Approach

During each test replicate, it was necessary to use not only a dip basket for capturing fish in the gatewells, but to use small hand nets for moving fish from holding tanks to a larger release tank. Also, since the exit flow from the CDS was in excess of 3.7 m/sec (12 ft/sec), it was necessary to subject the fish to a secondary dewatering system downstream from the CDS that allowed us to recapture and subsequently examine the test animals.

To ensure that our handling was not causing descaling/injury we released control groups of fish (generally about 100 fish) in the middle of the exit transition section of the CDS (Figure 1). A perforated plate dewatering screen (the secondary dewatering area) was used to dissipate excess water and allow us to recover the test fish. We then compared descaling results for test fish, which passed through the entire system, to those for control fish to assess the impacts associated with our release/recapture methodology. Standard fish descaling techniques as described in Ceballos et al. (1993) were used to categorize injuries.

During tests where both fish and debris were released together, we first began a gradual introduction of debris and then released the fish. We continued this procedure as each small group of fish was introduced. Video monitoring and visual observations were used to ensure that mixing was occurring (Gessel 2002, Video 3). To limit incidental descaling or injury we tried to remove most of the debris at the secondary dewatering screen so that our recapture efforts did not inadvertently descale or injure the fish.

Results and Discussion

Descaling results for the two tests conducted during the 2001 field season showed no obvious passage problems. All fish tested were recaptured and examined; descaling was 0% (0/130) for control fish and less than 1% (4/876) for test fish. Prior to the 2002 field season, the question was raised, "What effect does the CDS have on small subyearling chinook salmon (<50 mm fork length) that are present at McNary Dam in the early spring of each year?"

These fish are probably fry from wild fall chinook salmon spawning in the Hanford Reach, but the limited number collected made testing impractical. Therefore, to address this question we tested subyearling chinook salmon from the Little White Salmon Fish Hatchery on the lower Columbia River. Test fish were approximately 50 mm in fork length and were transported to the dam by truck in early April. We made a total of four releases from 12 April through 15 May 2002 (Table 1).

During the test period, fish were held at McNary Dam in river water and fed their normal diet, but at a reduced rate so that growth was minimal. We found no obvious injury or descaling problems for these fish. We also videotaped each of the releases (Gessel 2002, Video 2), and saw no indication of impingement at the downstream end of the CDS, where hydraulic testing conducted by the USACE indicated the highest impingement flows (>0.2 m/sec).

Descaling and injury data collected from the releases made during the 2002 juvenile migration indicated that little, if any, of the measured descaling or injury could be attributed to the CDS (see Table 3). During the spring tests, fairly small groups (<50 fish) of an individual species were often examined; therefore, all of the data for each species has been pooled, and only the means are provided. Tests with fish and debris were conducted during the late summer, and the descaling estimates presented were for subyearling chinook salmon only.

During the summer tests with subyearling chinook salmon, we were able to collect comparative descaling data for test and control fish (21 June-16 July, 8 test days, 4,300 fish). Results from these tests indicated there was no significant difference between descaling for test and control fish (0.7 % descaling, SE = 0.001; 0.4% descaling, SE = 0.002), respectively.

Table 3.Average descaling estimates (%) for juvenile salmonids tested in the cylindrical dewatering screen at McNary Dam during the 2002 field season.

	Yearling chinook	Coho	Steelhead	Sockeye	Subyearling chinook
Test fish	6.8	14.3	5.0	18.2	1.1
Control	7.3	11.1	6.0	15.8	0.5
Fish & debris tests					1.5

OBJECTIVE 3:Evaluate Debris Passage and Collection within the Cylindrical Dewatering Screen

Approach

The material used for the debris portion of the tests came from a variety of areas. Aquatic vegetation was gathered from shallow sloughs downstream from McNary Dam; leaves and grasses from shoreline areas; and straw, wood chips, pieces of dry thistle, and debris were retrieved directly from the juvenile collection facility at McNary Dam. Aquatic vegetation, leaves, wood chips, and thistles were used in conjunction with some subyearling chinook tests.

The debris was released into the center of the upstream end of the approach flume just off the floor. A 20-cm (8-in) diameter, 2-m (8-ft) long section of plastic pipe was attached to the grating that covered this portion of the flume. The pipe extended through the grating covering the flume to about 0.3 m (1 ft) from the floor. Debris was released into the flow by filling the pipe with 0.02 m^3 (5 gal) of debris, and then slowly pushing it out of the pipe.

To keep the debris from matting up into large masses as it passed downstream, the aquatic vegetation, thistle, and straw were chopped into small pieces (<15 cm). The debris was kept in containers and submerged prior to testing so that it would remain within the water column after release. For example, the wood chips required nearly 2 days of soaking to become somewhat neutrally buoyant. Videotape was used in some of the debris tests to monitor passage within the CDS (Gessel 2002, Video 4). Estimates of the amount of debris removed by the CDS were not attempted when the video camera was submerged.

Results and Discussion

Table 4 gives the results for the different types of debris tests that were conducted during the two-year study period. Standard flow conditions used during the fish tests were also used during all of the debris tests. The amounts of debris used and the amount removed are gross estimates based on the size of containers used to soak the debris, and the number of 5-gal buckets (0.02 m^3) of debris that were removed. As is evident from Table 4, very little debris was actually impinged or removed during any of the replicates.

Table 4. Cylindrical dewatering screen debris tests conducted at McNary Dam during the juvenile salmonid spring and summer migrations of 2001 and 2002. (Aqv = aquatic vegetation, Str = straw, Ths = thistles, Lvs = leaves)

Date	Flow condition	Debris type	Debri released	Debri recovered	
			(m^3)	(m^3)	(%)
6-15-2001	Standard	Aqv	0.8	0.07	1
7-16-2001	Standard	Aqv	1.0	0.06	1
7-18-2001	Standard	Aqv	0.8	0.05	1
7-19-2001	Standard	Aqv & Str	1.0	0.06	1
7-26-2001	Standard	Aqv & Str	0.7	0.06	1
7-27-2001	Standard	Aqv & Ths	3.0	0.16	2
7-30-2001	Standard	Aqv & Ths	1.0	0.06	1
7-31-2001	Standard	Aqv, Ths, Lvs	2.5	0.15	2
8-01-2001	Standard	Aqv, Ths, Lvs	3.0	0.15	1
8-02-2001	Standard	Aqv, Ths, Lvs	1.0	0.05	1
8-03-2001	Standard	Aqv, Ths, Lvs	1.5	0.07	2
8-07-2001	Standard	Wood chips	1.0	0.08	2
8-08-2001	Standard	Wood chips & Aqv	1.5	0.1	2

Review of the underwater video showed that almost all types of debris simply slid along the walls of the CDS (Gessel 2002, Video 4). Small woody pieces did lodge between screen panels or in the interstices of the parallel bars, but this was generally just a momentary pause in movement. The only area that had appreciable impingement was the extreme downstream end of the CDS (this was also the area of greatest concern for possible juvenile fish impingement). Debris in this area did impinge, and the spray bars set up to wash debris from the interior of the screen did remove some of this debris. Generally, most debris that impinged remained on the screen panels until the panels rotated out of the water. The debris then fell into the CDS flow due to gravity and washed downstream (Gessel 2002, Videos 5 and 6).

The type of debris most likely to create hazardous passage conditions for fish appeared to be wood chips (Gessel 2002, Video 7). This material created the largest amount of blockage even when the CDS was rotating. Like all other types of debris, wood chip impingement occurred primarily at the exit point of the CDS, but the wood chips accumulated much faster than other types of debris.

It appeared that wood chips offered sufficient surface area for impingement, while the stiffness of each chip and the surface irregularity allowed water to pass between the individual chips and dissipate through the screen. During several wood chip tests, we did not rotate the CDS, and the last two screen sections were quickly covered in wood chips to a depth of 8-10 cm (3-4 in) (Gessel 2002, Video 8).

As a potentially "worst case" situation, we released approximately 100 gal (2 m^3) of wood chips into the CDS while it was not rotating. We then made several releases of subyearling chinook salmon and monitored their movement. Review of the video tapes indicated that even under these conditions, fish did not appear to have any passage problems (Gessel 2002, Video 9).

CONCLUSIONS AND RECOMMENDATIONS

1) The cylindrical dewatering screen did not appear to have any fish passage problem areas. Some fish did linger in the approach flume, but once fish began to move downstream they almost all passed completely through the system. For each species tested, fish that remained in the flume were significantly larger than those that exited.

2) Results from fish condition evaluations showed no differences in injury or descaling between control and test fish, and we concluded there were no problem areas within the cylindrical dewatering screen. A small increase in descaling did occur when fish and debris were tested together, but this increase was very possibly related to our handling techniques when the fish were recaptured. We saw no visual evidence of fish contacting debris during passage.

3) A variety of debris types were tested in the cylindrical dewatering screen. Very little debris was impinged, and impingement occurred at the exit point of the CDS. We estimated that less than 5% of the debris volume released was removed by the CDS.

ACKNOWLEDGMENTS

We would like to express our appreciation to NMFS seasonal personnel for their enthusiasm and efforts during this study. We extend special thanks to the Walla Walla District USACE personnel, particularly Mr. Fred Higginbotham at the District Office and Mr. Brad Eby, Project Biologist at McNary Dam, for their assistance and cooperation in this study. We also want to acknowledge the innovative design and expert craftsmanship employed by NMFS Pasco Field Station personnel assisting in this study, in particular by Mr. Ira Brickey, Mr. Wayne Henry, Mr. Irv Wilbert, and Mr. Bill Wassard.

REFERENCES

Gessel, M. H. 2002. Cylindrical Dewatering Screen. Videotape records of evaluation for the cylindrical dewatering screen at McNary Dam, 2001-2002. Available via the internet in a series of nine audio video interleaved (avi) files at http://www.nwfsc.noaa.gov/research/divisions/fed/fishpassage/cylindrical.cfm (accessed March 2004).

Ceballos, J. R., S. W. Pettit, J. L. McKern, R. L. Boyce, and D. F. Hurson. 1993. Fish Transportation Oversight Team Annual Report--FY 1992. Transport operations on the Snake and Columbia Rivers. NOAA Tech. Memo. NMFS F/NWR-32.

NMFS (National Marine Fisheries Service). 1995. Juvenile fish screen criteria, revised February 16, 1995. Available from NMFS, HydroProgram, 525 N.E. Oregon St., Suite 500, Portland Oregon 97232.

NMFS (National Marine Fisheries Service). 2000. Endangered Species Act, Section 7 Consultation, Biological Opinion: Reinitiation of consultation on operation of the Federal Columbia River power system, including the juvenile fish transportation program and 19 Bureau of Reclamation projects in the Columbia Basin. Available www.nwr.noaa.gov/1hydrop/hydroweb/docs/ Final/2000Biop.html (July 2003).

Swan, G. A., R. F. Krcma, and W. E. Farr. 1979. Dipbasket for collecting juvenile salmon and trout in gatewells at hydroelectric dams. Prog. Fish-Cult. 41(1):48-49.